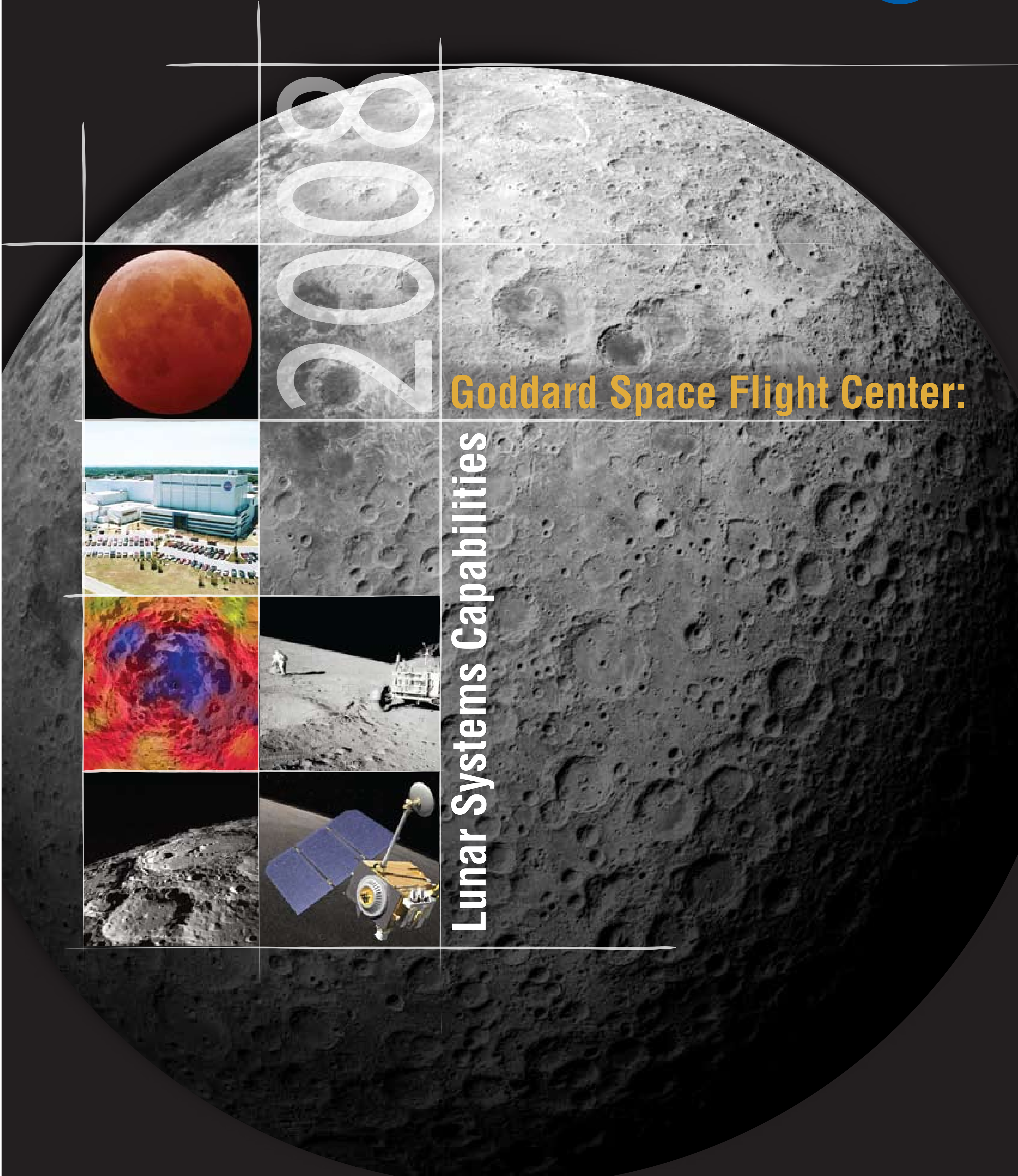
National Aeronautics and Space Administration

Goddard Space Flight Center: Lunar Systems Capabilities

2008



Goddard Space Flight Center: Lunar Systems Capabilities

The whole is greater than the sum of its parts…

The Goddard Space Flight Center (GSFC) believes in this adage and is proud to be a member of the Exploration Systems Mission Directorate's "nationwide" team.

We have prepared this catalog as a means to begin a conversation…a conversation about the products and capabilities that GSFC can bring to the Lunar Surface Systems initiative to complement the diverse skills and strengths offered by other NASA Centers.

We invite you to explore the full range of the Center's innovation and creativity, which were borne from our rich heritage in human spaceflight and robotic flight missions. You are invited to visit our Web site at **http:explorationatgoddard.gsfc.nasa.gov** or to contact us for more details and demonstrations.

We look forward to the conversation…

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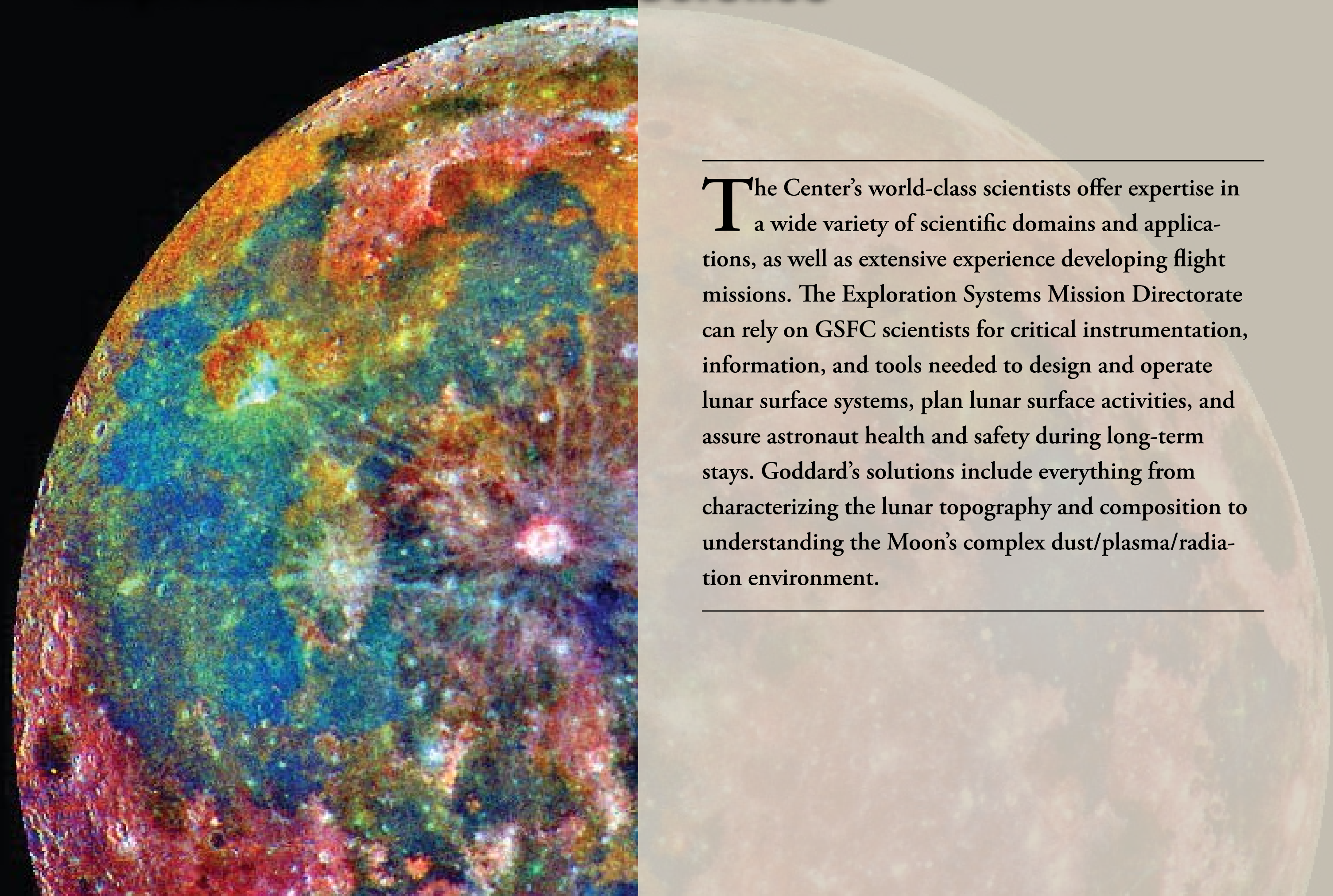
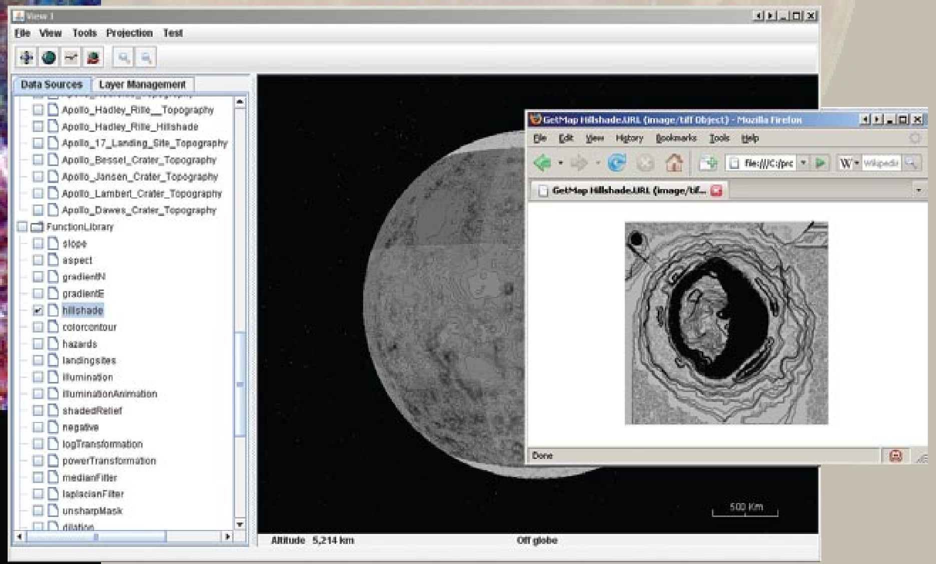
Exploration To Enable Science



The Center's world-class scientists offer expertise in a wide variety of scientific domains and applications, as well as extensive experience developing flight missions. The Exploration Systems Mission Directorate can rely on GSFC scientists for critical instrumentation, information, and tools needed to design and operate lunar surface systems, plan lunar surface activities, and assure astronaut health and safety during long-term stays. Goddard's solutions include everything from characterizing the lunar topography and composition to understanding the Moon's complex dust/plasma/radiation environment.



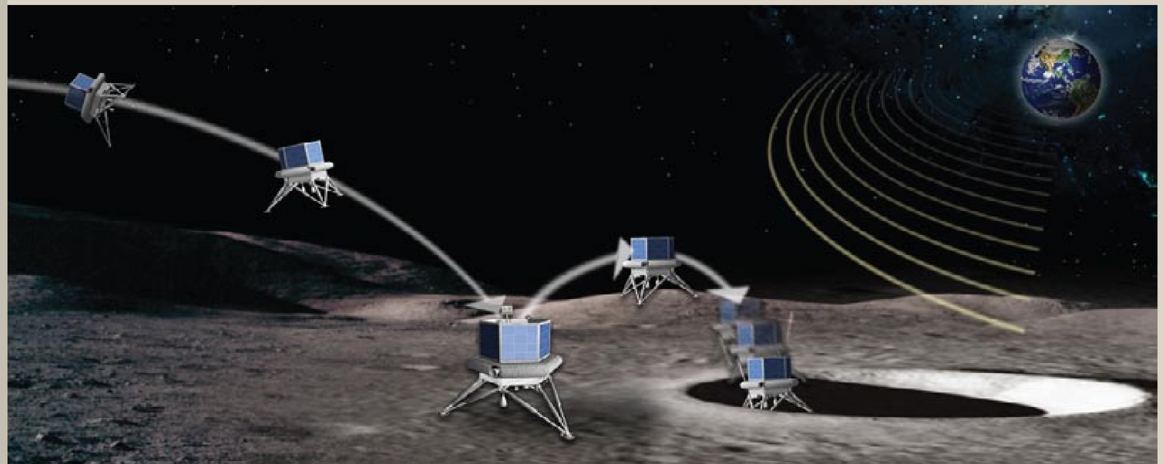
ILIADS is a geospatial information system that will give mission planners easy access to satellite and other lunar data so that they can create visualizations and conduct "what-if" analyses to select potential outpost sites on the Moon and plan astronaut activities once there.

Lunar Reconnaissance Orbiter (LRO) The LRO mission is NASA's first step in returning humans to the Moon. The spacecraft, which will launch in late February 2009, carries a suite of seven instruments that will provide the most comprehensive data set ever returned from the Moon — information NASA will use to design and build the planned lunar outpost. During its 12-month mission, the polar-orbiting LRO specifically will focus on identifying safe landing sites and lunar resources, and studying how the lunar radiation environment will affect humans. Contact: Craig.R.Tooley@nasa.gov.

Integrated Lunar Information Architecture for Decision Support (ILIADS) With this advanced geospatial information system, mission planners will be able to retrieve satellite and other lunar data, create visualizations, and conduct "what-if" analyses to select potential robotic landing and crew habitat sites in the near term. ILIADS also will allow planners and crewmembers to plan and direct real-time crew activities when the Agency establishes permanent outposts later next decade. Contact: Stephen.J.Talabac@nasa.gov.

Lunar Explorer (LEx) The proposed Lunar Explorer and its science-application extension, the In-Situ Flyer, is a vehicle based on Exo-atmospheric Kinetic Vehicle technologies, which have been combined with a flight-proven, high-thrust liquid propulsion system and braking-descent landing algorithms to perform multiple takeoffs and precision landings. This capability offers an unparalleled mobility system for science and engineering applications, including environmental reconnaissance or network and payload deployment. This "go-anywhere" mobility system complements surface-only mobility systems. Contact: Joe.Burt@nasa.gov.

The proposed Lunar Explorer and the In-Situ Flyer offer an unparalleled mobility system for science and engineering applications on the Moon.



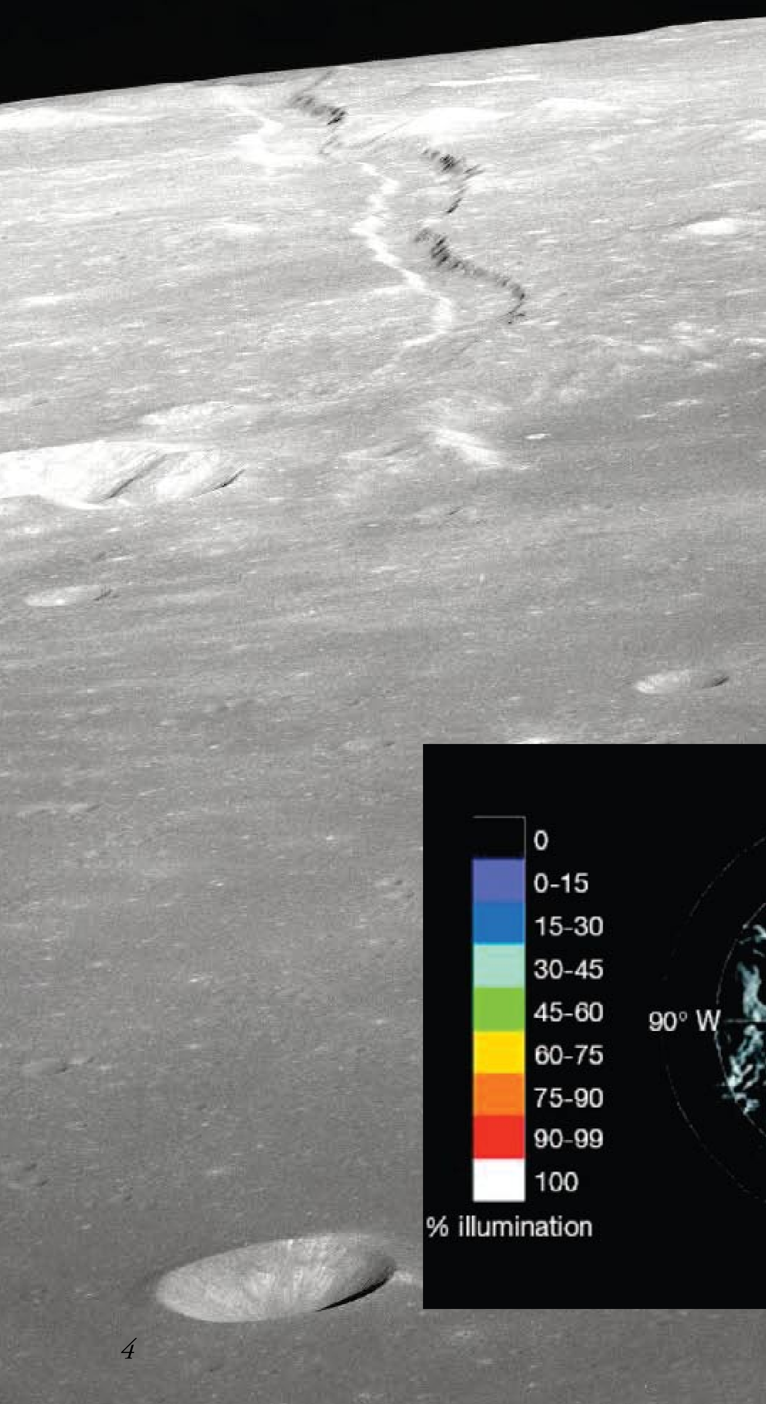
During his 24-year career as a NASA scientist, GSFC Sciences and Exploration Division Chief Scientist Jim Garvin has pursued such disciplines as Earth system science, Mars exploration, lunar exploration, Venus, asteroids, and the outer planets. He embodies the wide-ranging expertise available at GSFC.

Lunar Deployable Telescope Scientists have been exploring potential ways to use the Moon's surface to carry out astronomical observations. One idea currently under investigation is the development of a Lunar Deployable Telescope, a modest aperture telescope that would include a high-precision, visible-light CCD spectrophotometer capable of studying transiting extrasolar planets. Contact: Leo.D.Deming@nasa.gov.

Lunar Drills for Subsurface Science As a part of ongoing research activities, engineers are developing lunar drill strings and test equipment for science applications. The drill strings, which include a heat-flow probe, regolith temperature probe, and a coring string, are tested in a newly completed 10-meter drill test tube filled with dry lunar stimulant. Driven by science requirements, each of the units is 10 meters long. The work is a collaborative effort involving GSFC, Texas Tech, and Honeybee Robotics. Contact: Malcom.B.Milam@nasa.gov.

The Lunar Reconnaissance Orbiter mission is designed to collect the highest-resolution and most comprehensive data set ever returned from the Moon — data needed to safely return human explorers to the Moon in preparation for an eventual mission to Mars.

Lunar Surface Topography and Composition

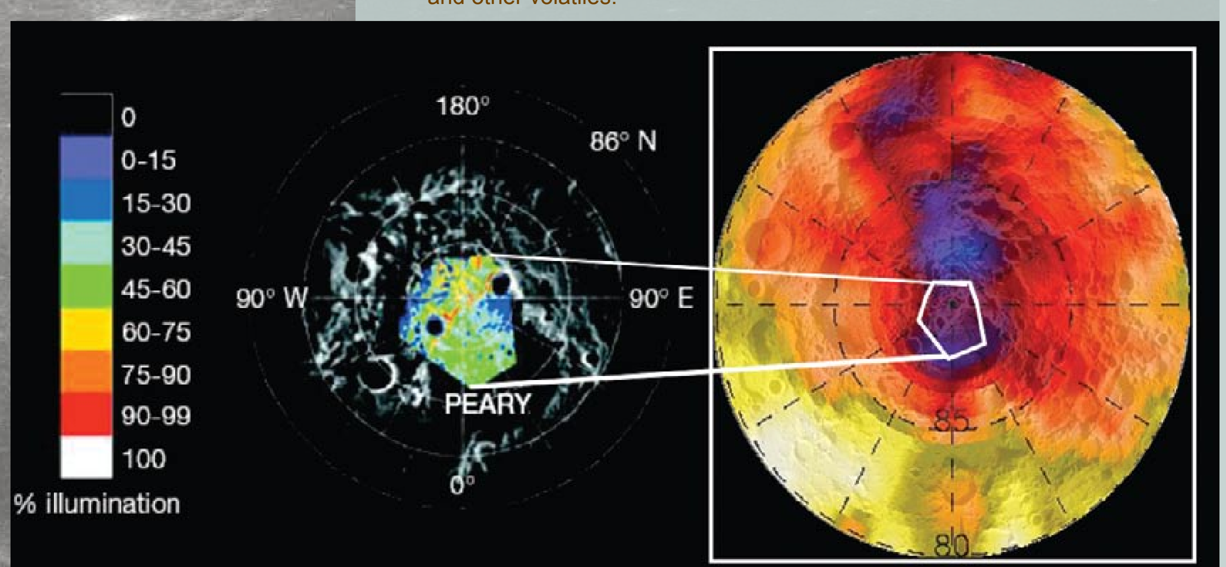


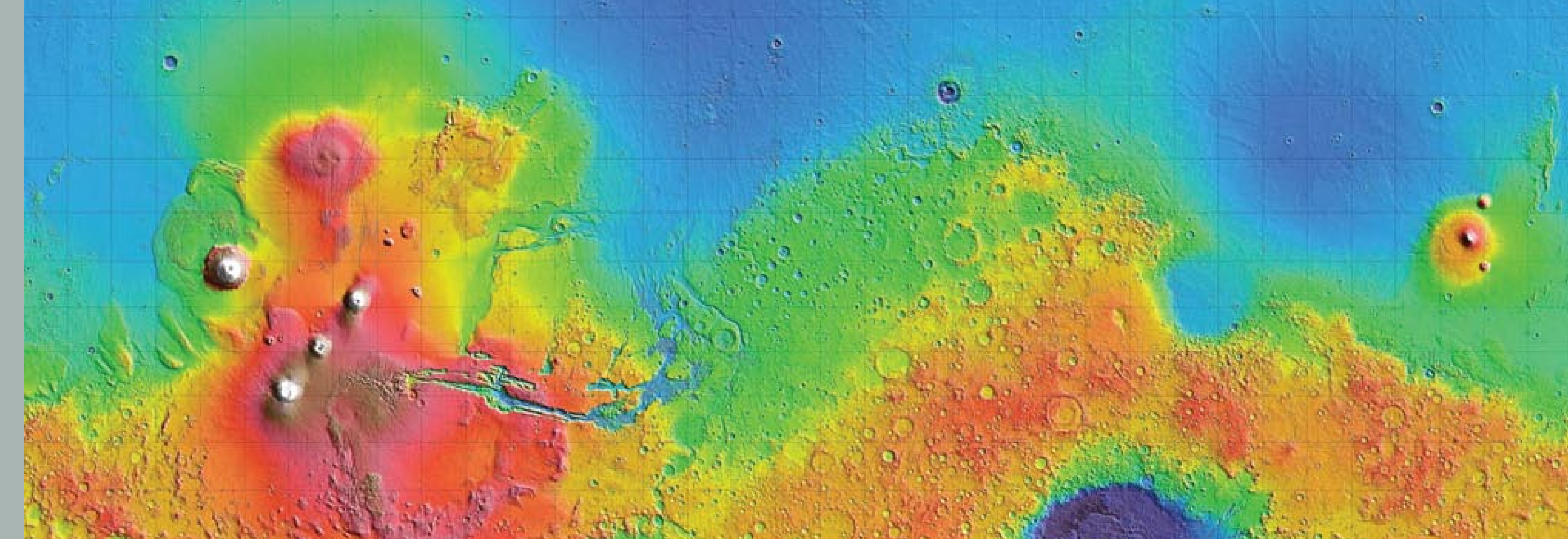
Scientific instruments, sensors, and analytical tools that can provide three-dimensional maps of the Moon's surface and reveal its mineral resources and other geophysical and chemical characteristics are needed to optimize the design of exploration assets and effectively plan activities when astronauts return to the Moon for extended stays. The Center employs many of the world's leading researchers in these areas — experts who already have begun developing tools that will provide greater insights into the Moon's composition and topography.

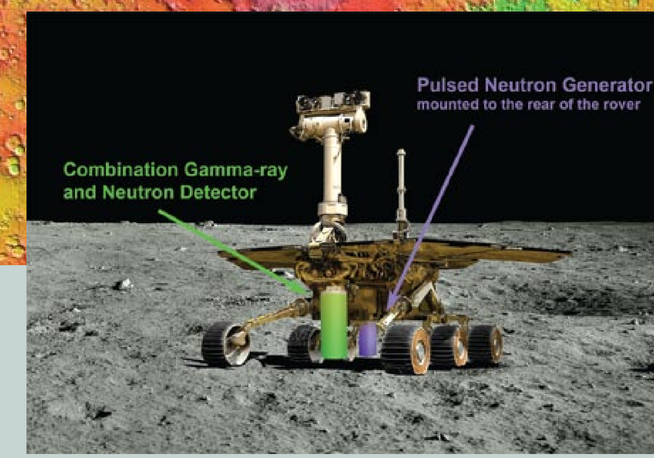
Lunar Orbiter Laser Altimeter (LOLA)

LOLA is one of seven instruments flying on the Lunar Reconnaissance Orbiter (LRO) mission and the fourth generation of GSFC-developed laser altimeters that included the Mars Orbiter Laser Altimeter launched in 1996, the Mercury Laser Altimeter launched in 2004, and the Geoscience Laser Altimeter System launched in 2003. Unlike its predecessors, LOLA's laser beam will split into five separate beams when it passes through a diffractive optical element. Each of the beams will map to five independent receivers to produce more than 4 billion measurements of the lunar surface. The result will be a three-dimensional map that is more precise, in fact, than three-dimensional maps of the Earth's surface. LRO/LOLA data and derived products will form the basis of all lunar mapping products to be used for lunar surface operations. Contact: Anthony.W.Yu@nasa.gov.

The Clementine image on the left and the Lunar Prospector image on the right reveal areas that contain higher levels of hydrogen. The VAPoR instrument can carry out in situ analyses of these areas to determine the origin and abundance of water and other volatiles.







When mounted to a rover, the Pulsed Neutron Generator-Gamma-Ray and Neutron Detector (PNG-GRAND) will survey bulk elements down to about 30 centimeters below the lunar surface without penetrating or touching the surface.

Sample Analysis at Mars (SAM)

One of the most complex experiments ever planned for planetary exploration, this chemical processing lab will analyze gases in the Martian atmosphere and those that are produced when a miniaturized onboard oven heats soil and rock samples to search for compounds of carbon, including methane. It also will look for and measure the abundances of other light elements (hydrogen, oxygen, and nitrogen) that also are associated with life. The instrument is one of several on the Mars Science Laboratory, which is expected to launch in 2009. Instruments such as this can be developed by GSFC's planetary scientists for the Moon, Mars, and beyond. Contact: Paul.R.Mahaffy@nasa.gov.

X-ray Fluorescence/X-ray Diffraction (XRF/XRD) Instrument

XRD is the gold standard for identifying minerals, while XRF reveals their elemental composition. Technologists are working on a concept that will combine these capabilities into one instrument. An added benefit is that the instrument will require no special sample preparation, making it especially ideal for searching for valuable resources, such as water ice, on the lunar surface. Contact: Keith.C.Gendreau@nasa.gov.

The GSFC-developed Mars Orbiter Laser Altimeter obtained this high-resolution map of the Martian surface. Because of technological advances, the Lunar Orbiter Laser Altimeter is expected to generate an even more precise topographical map of the Moon.

Volatile Analysis by Pyrolysis of Regolith (VAPoR)

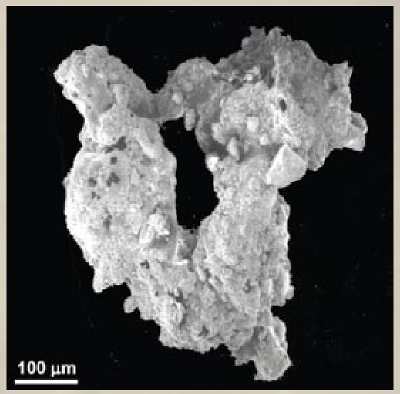
VAPoR is a suitcase-sized instrument that measures the abundance and isotopic composition of water and other volatiles in the Moon's regolith and tenuous atmosphere — measurements that NASA already has cited as important to understanding the lunar environment. With its long history of developing successful flight mass spectrometers, including the Sample Analysis at Mars instrument suite on the Mars Science Laboratory, GSFC is uniquely qualified to develop such an important tool. Contact: Daniel.P.Glavin@nasa.gov.

Pulsed Neutron Generator-Gamma-Ray and Neutron Detector (PNG-GRAND)

This proposed instrument, which leverages the Center's considerable expertise in gamma-ray science, would provide a complete survey of elements found on the Moon. Capable of measuring elemental abundances over a square-meter area and down to 30 centimeters in depth, the instrument is ideal for taking an initial inventory of lunar resources. It also can monitor the complete lunar radiation environment, measuring gamma rays, neutrons, and charged particles. It complements the XRF/XRD instrument also described in this section. Contact: Ann.M.Parsons@nasa.gov.

Lunar Environment

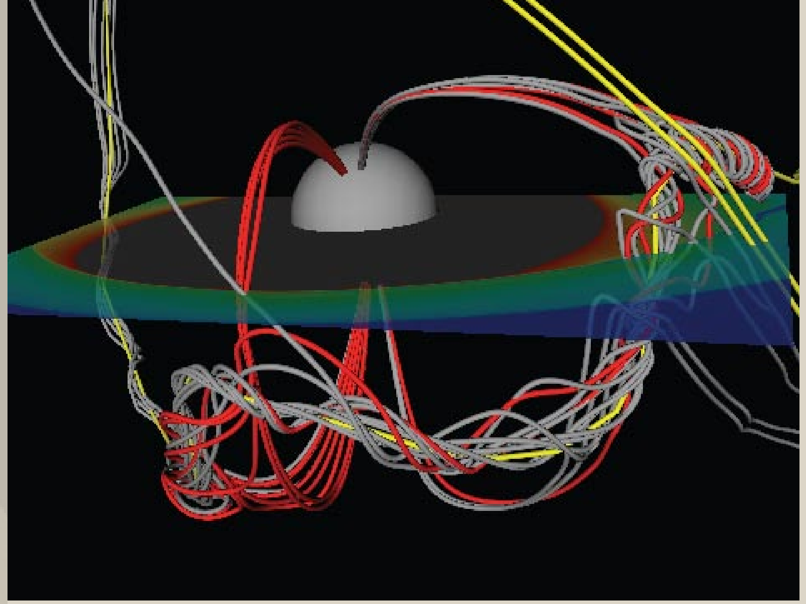
The lunar surface is directly affected by events that occur on the Sun. Solar storms that release plasma and highly energetic particles threaten explorers and the equipment they will use. However, scientific instruments, sensors, and analytical tools can help mitigate the dangers that human explorers will encounter. The Center employs experts in the fields of radiation, plasma, dust, and highly complex environmental systems. As part of their research, these experts are making significant progress to better understand this environment and its potential impact on human exploration of the Moon, Mars, and beyond.



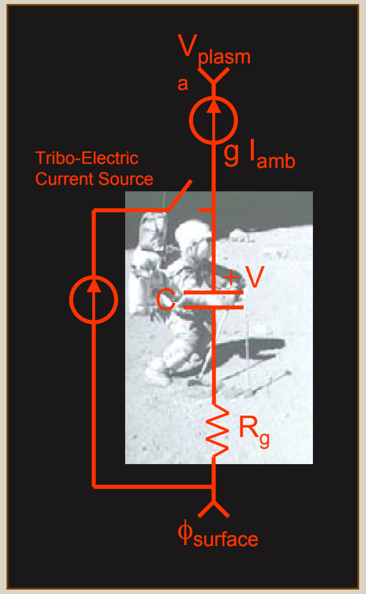
Lunar dust particles are highly electrostatic and sharply barbed, which means they cling to everything with which they come into contact. This creates challenges for astronauts and surface elements.

Space Weather Forecasts Knowing when a solar event may occur is the first line of defense in protecting lunar explorers and their equipment. GSFC is home to the Community Coordinated Modeling Center (CCMC), a multi-agency service that researches next-generation science and operational space weather models. The goal now is to dramatically improve scientists' ability to forecast these solar particle events and develop tools that will make the information available to those who need it both on Earth and the Moon. GSFC scientists, meanwhile, are studying the potential ramifications of these events on the lunar surface. Contact: Michael.Hesse@nasa.gov.

Dynamic Response of the Environment At the Moon (DREAM) Solar storms can influence the Moon's local plasma and neutral atmosphere, resulting in extremes in surface charging and the transport of dust. DREAM is a set of modeling tools to predict these effects and help influence decisions regarding the advisability of extravehicular activities. Contact: William.M.Farrell@nasa.gov.



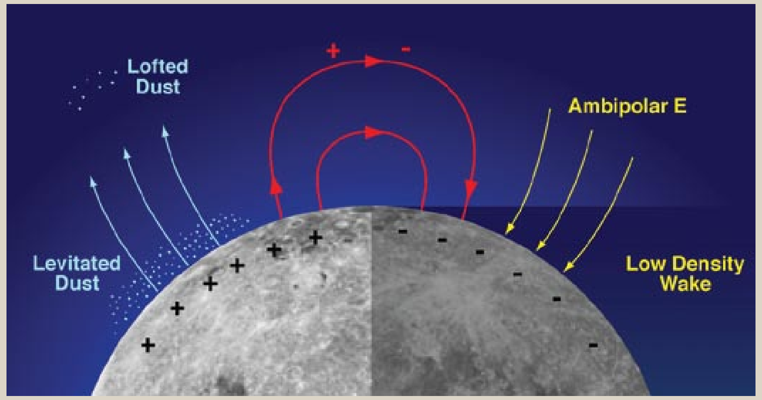
The Community Coordinated Modeling Center researches next-generation science and operational space weather models, such as the one shown here. The purpose is to improve scientists' ability to predict solar particle events.



Dynamic Response of the Environment At the Moon (DREAM) is a set of modeling tools to predict extremes in surface charging and the transport of dust. This DREAM model shows the path for the charge build-up as an astronaut navigates the lunar surface.

Mini-Mass Time-of-Flight Spectrometer (Mini TOF-MS) GFSC's expertise in planetary mass spectrometry and micro- and nano-fabrication techniques are being leveraged to create a novel application needed for human spaceflight — air-quality monitoring. Technologists are developing the Mini TOF-MS, which features a low-power carbon nanotube field emitter array. The compact, low-mass, low-power instrument ultimately will be capable of detecting all volatile species on the Orion Crew Exploration Vehicle and the Altair Lander with a single air-quality monitoring system. Current air quality monitors rely on four systems. Contact: Todd.T.King@nasa.gov.

On the day-side of the Moon, dust particles are positively charged. On the night-side, they are negatively charged. The situation gets interesting where the two sides meet. The transition could create more complex and stronger electric fields, further accelerating dust particles.



Lunar Emissions, Electrons, and Dust (LEED) To monitor the local lunar weather, GSFC has begun developing LEED — a dusty-plasma environmental instrument that can provide real-time observations of local surface charging, E-fields, plasma, and any moving dust. Astronauts can use LEED to determine environmental hazards posed by extreme surface charging, dust acceleration, and tribo-charging dissipation. Contact: William.M.Farrell@nasa.gov.

Particle Image Velocimeter (PIV) On the Moon, ultra-small, sharply barbed dust grains levitate in all directions, adhering to everything with which they come into contact. Before developing strategies for mitigating the problem, NASA first needs to understand the physical processes that create this environment. The PIV will give scientists an unprecedented ability to measure particle sizes, concentrations, and velocities. Contact: Brent.J.Bos@nasa.gov.

Lunar Radiation Environment Monitor With the addition of a solid-state, charged-particle shield, GSFC's proposed Gamma Ray and Neutron Detector (GRAND) instrument becomes the ideal tool for monitoring the complete radiation environment on the lunar surface. GRAND has the unique capability of measuring the intensity of gamma-ray, neutron, and charged-particle radiation with a single, hand-held instrument. Whether part of a radiation-monitoring network or used as a hand-held survey instrument for astronauts, GRAND will provide information vital for astronaut health. Contact: Ann.M.Parsons@nasa.gov.

Dust Mitigation

Through scientific analyses of the micro and macro properties of lunar dust, GSFC engineers have developed several innovative mitigation approaches. To test and verify new dust-mitigation instruments and techniques, the Center has developed a chamber to realistically simulate both lunar and Martian environments.

The Dust Environmental Effects Particle chamber gives scientists and engineers the capability to test ground-based hardware in simulated lunar and Martian dust environments.

Dust Environmental Effects Particle (DEEP) Chamber Measuring 1.2 meters in diameter and 1.8 meters in length, the DEEP chamber gives scientists and engineers the capability to test ground-based hardware in simulated lunar and Martian dust environments. With this chamber, they are able to characterize the effect of lunar and Martian dust on surfaces, including degradation-sensitive mechanisms, instrument surfaces, microshutters, optics, solar arrays, and thermal control and other special coatings. Contact: Sharon.A.Straka@nasa.gov

The lotus plant has inspired materials engineers to create a coating that mimics the plant's unusual self-cleaning capabilities. Engineers are now investigating whether materials treated with these coatings can survive the harsh lunar environment.

Lotus Coatings The lotus plant has inspired materials engineers and chemists to create a coating that mimics the plant's unusual self-cleaning/anti-contamination properties. GSFC is now investigating whether "lotus coatings" can survive the harsh lunar environment and minimize Moon dust from accumulating on astronauts, their gear, and external spacecraft/habitation surfaces. Contact: Wanda.C.Peters@nasa.gov.

Dust Mitigation Vehicle (DMV) GSFC has been working on techniques to vaporize lunar soil or regolith using nothing more than focused sunlight. This technology has lead to a vehicle concept — the DMV — that will prevent dust from getting into lunar habitats by "paving" the area around the base. Under the concept, a Fresnel lens or a single lightweight mirror will be attached to the vehicle. The lens then focuses sunlight onto the lunar surface to either melt or sinter the regolith, depending on the type of surface desired. Contact: Eric.H.Cardiff@nasa.gov.

Moon Portable Electrostatic Detector (MoPED) This stand-alone, miniaturized electrometer detects surface charging on spacesuits and equipment, giving astronauts real-time readings of their static charge as well as those of the equipment they are handling. Using this pencil-sized device to get real-time readings, astronauts can dissipate their charge before handling equipment and potentially creating a discharge hazard that can injure them or their equipment. Contact: Telana.L.Jackson@nasa.gov.

This is a prototype of the Dust Mitigation Vehicle, which will help control the lunar dust problem around lunar bases by melting or "paving" the regolith.

Communications

Since its inception, the Center has led human spaceflight and near-Earth robotic communications for the Agency. It develops in-house, state-of-the-art communications and tracking flight hardware, including standards and technology for high-rate and networked communications. The Center currently manages the Space Network and Near-Earth Network and ensures the vitality of these critical systems. In addition, GSFC has led the definition of laser communications for future infrastructure upgrades and remains committed to providing the highest-quality service in terms of reliability, innovation, and resource efficiency for all Agency programs.

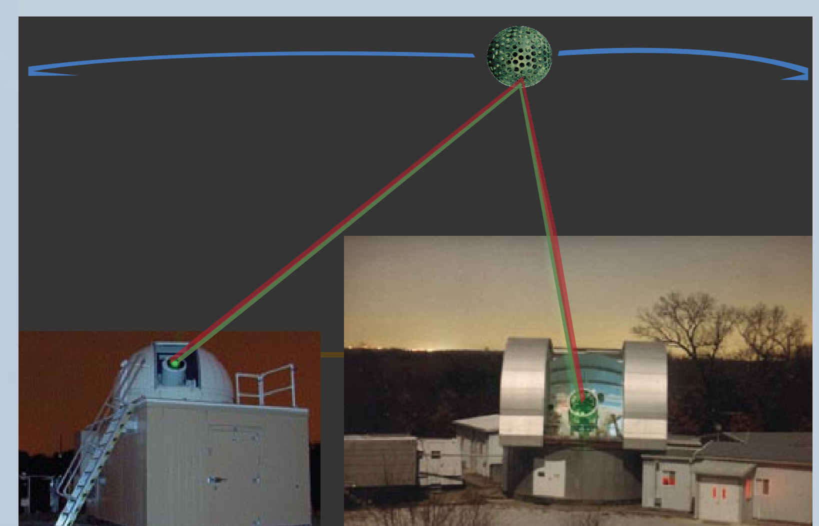
GSFC'S Communications, Standards, and Technology Lab provides a high-fidelity, end-to-end IP communications test and demonstration environment for NASA programs.

Communications, Standards, and Technology Laboratory (CSTL) The CSTL provides a high-fidelity, end-to-end IP communications test and demonstration environment for the NASA Space Communications and Navigation Standards and Technology programs. It is a prime facility for space communications and navigation studies, Constellation C3I and lunar surface studies, and space network and ground network prototyping activities. The testbed is currently configured to demonstrate C3I interoperability, standards-based IP communications for a lunar surface scenario that includes the use of wireless technologies, a lunar surface communications base station, lunar relay, Earth ground stations, and mission control. Contact: David.J.Israel@nasa.gov.

Goddard ElectroMagnetic Anechoic Chamber (GEMAC) GEMAC is a world-class facility for measuring antenna patterns and the performance of microwave instruments over the frequency range of 400 MHz to 100 GHz. This facility was recently used to test Ka-band High-Gain Antennas for the Solar Dynamics Observatory and the Lunar Reconnaissance Orbiter. It also calibrated and characterize the Wilkinson Microwave Anisotropy Probe. Contact: Rene.B.Gosselin@nasa.gov.

High-Frequency Structure Simulator (HFSS) and Designer HFSS is an excellent tool for designing individual passive microwave components, including antennas, feeds, diplexers, polarizers, waveguides, and loads. Designer, meanwhile, is a RF schematic and design tool for solving system, circuit, and planar electromagnetic problems. Contact: Rene.B.Gosselin@nasa.gov.

GSFC has been leading innovations in laser-based communications and is planning the first high-rate, free-space laser communications link from the Moon back to Earth.



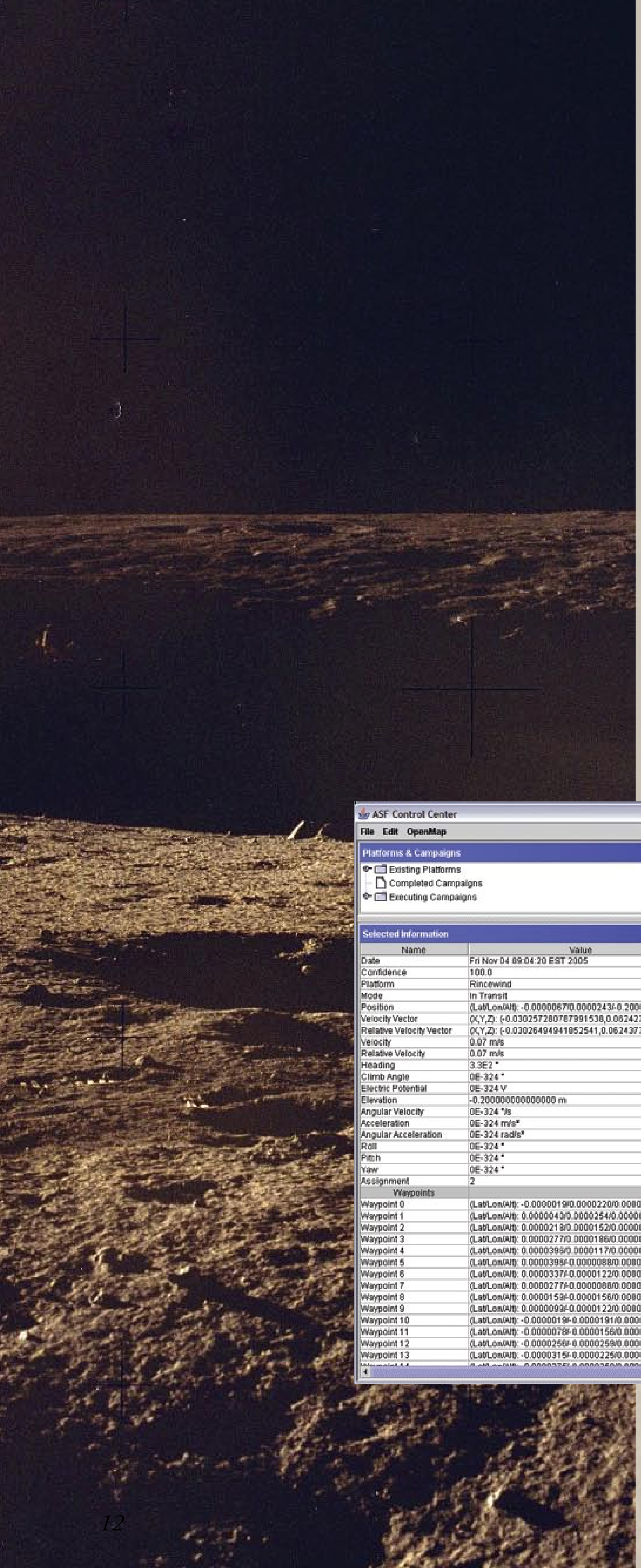
The Goddard ElectroMagnetic Anechoic Chamber is a world-class facility for measuring antenna patterns and the performance of microwave instruments over the frequency range of 400 MHz to 100 GHz.

General Reflector and Antenna Far Analysis Software (GRASP) GRASP is an electromagnetic physical optics and diffraction software package that calculates RF currents on objects and the resulting electric fields. It is ideal for designing and analyzing ground- and space-based reflector antennas and spacecraft effects on antenna performance as well as for predicting field strengths on critical areas. Contact: Rene.B.Gosselin@nasa.gov.

RF Analysis This tool analyzes the RF interface for missions using both space and ground networks. The primary analytical tool is the Communications Link Analysis System (CLASS), which consists of a suite of tools that are used together or combined with others to solve specific problems. CLASS tools include the Antenna Radiation Pattern Analysis Tool; Ground User Interference Determination Evaluation; Automated Conflict Resolution System; and Phase Noise Analysis Tool. Contact: Frank.J.Stocklin@nasa.gov.

Laser Communications High-bandwidth communications is an important capability for human and robotic exploration of the Moon and Mars. GSFC has been leading innovations in laser-based communications by leveraging Defense Department investments. The Center and its partners are planning the first high-rate (hundreds of Mbps), free-space laser communications link from the Moon back to Earth. Contact: Michael.A.Krainak@nasa.gov.

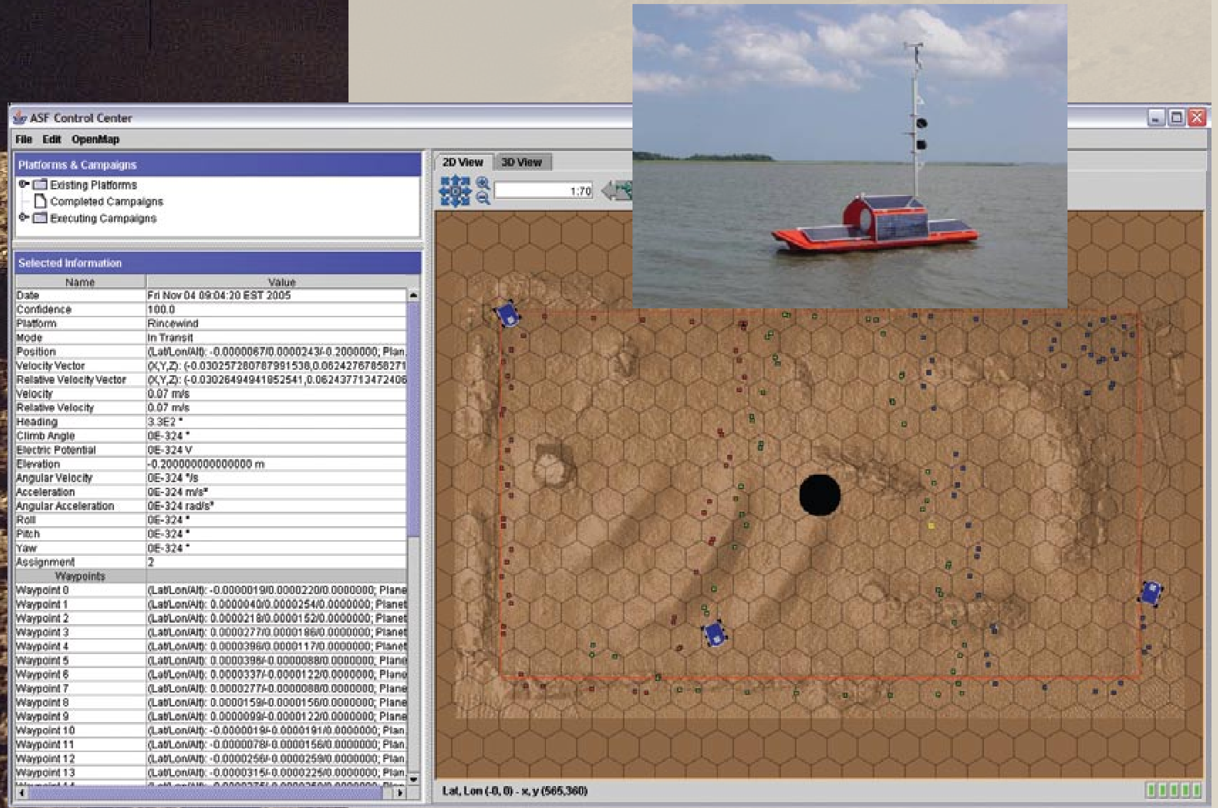
Surface Navigation



GSFC has experience in mission-critical human spaceflight navigation. As the assigned lead for surface navigation, the Center has identified and analyzed the unique technical challenges of navigating on the Moon's surface and is actively working to address them.

Lunar Navigation Determination System (LaNDS)

LaNDS is a comprehensive navigational system that both robotic and human explorers can use to determine their bearings on the lunar surface. The system will combine robust processing power with an extensive topographical database to create a real-time atlas that shows surface features, mineral compositions, star fields, Earth and Sun positions, and the precise locations of habitats, rovers, lunar communications terminals, lunar relay satellites, and other lunar surface elements. In addition, LaNDS will be able to autonomously control and monitor fleets of unmanned rovers and static science payload stations. LaNDS will accept inputs from inertial-measurement, optical (visible, LASER and LIDAR, and X-ray) and radio frequency (1-way, 2-way ranging, RADAR, and weak GPS signals) sensors. Contact: Richard.J.Lynch@nasa.gov.



The Adaptive Sensor Fleet technology is a dynamic software system that tasks, monitors, and controls a diverse group of instrument-equipped robotic vehicles, including boats, to autonomously and collaboratively gather in situ measurements.

Navigator is a space-qualified Global Positioning System receiver designed to work in weak-signal environments. Its dimensions are 10-1/2 inches by 10-1/2 inches by 4 inches.

Weak GPS Receiver

Navigator is a space-qualified Global Positioning System (GPS) receiver designed to work in weak-signal environments, specifically those found in highly elliptical or geosynchronous orbits. It is slated to fly as part of a Remote Navigation Sensor experiment on the Hubble Space Telescope Servicing Mission-4 as well as on GOES-R in 2012. The Magnetospheric Multiscale Mission, which is made up of four identical spacecraft that will fly in formation to explore the interaction of Earth's magnetic field with the solar wind, also will carry the technology. In addition, it is being explored for possible use on the Orion/Crew Exploration Vehicle for navigation in trans-lunar orbits. Contact: John.C.Adams@nasa.gov.

Hazard Avoidance and Position Control

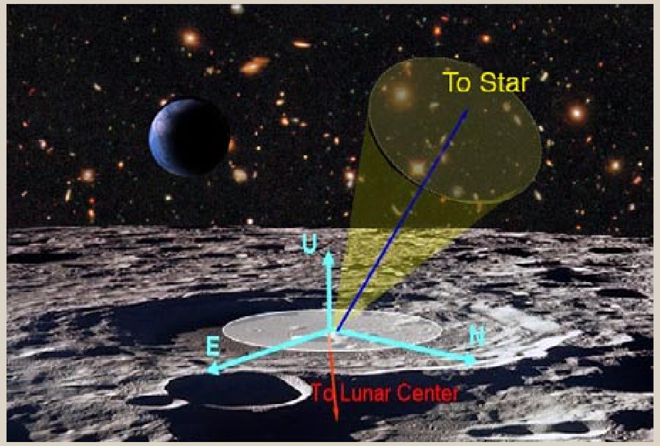
GSFC is now working to demonstrate a three-dimensional flash ladar capable of precise ranging, altimetry, and imaging—capabilities that NASA needs to locate obstacles during landing, carry out autonomous docking maneuvers on the Moon, and avoid hazards while navigating the surface. The effort leverages the Center's considerable R&D investments in this technology area, including the advance of state-of-the-art detectors. It also takes advantage of advances made by the Defense Department and private industry. Contact: Tony.Yu@nasa.gov.

Adaptive Sensor Fleet (ASF)

ASF is a dynamic software system that tasks, monitors, and controls a diverse group of instrument-equipped robotic vehicles to autonomously and collaboratively gather in situ measurements on the lunar surface. With this technology, scientists simply identify the target area and measurement goals. The system's fleet manager then divides the work, directs each platform to the site, and monitors and analyzes each platform's progress, making adjustments when necessary. Contact: Jeff.Hosler@nasa.gov.

Celestial Navigation (CelNav)

This is a method by which the location and attitude of a landed lunar asset is determined using measurements provided by star tracker(s) and an accelerometer. In short, longitude and latitude information is determined autonomously to independently confirm an asset's location. In 2006, under the NASA and ASEE-funded Faculty Fellowship Program, GSFC developed a MATLAB algorithm to investigate lunar surface navigational errors. The goals of upcoming projects include modifying code to implement NASA GSFC star tracker Simulink models; testing the algorithm with the implemented star tracker models; and further confirming the reliability and performance of the CelNav algorithm for determining lunar surface coordinates given different types of lunar terrain. Contact: David.C.Folta@nasa.gov.

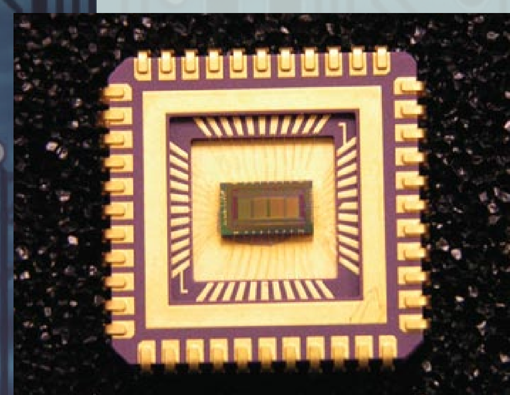


Lunar surface navigation is a method by which the location and attitude of a landed lunar asset is determined using measurements provided by one or more star trackers and an accelerometer. This artist's rendering shows a potential concept.

Avionics and Software

Avionics

GSFC's laboratories and techniques for integrating, verifying, and validating spaceflight avionics have consistently produced successful spaceflight missions, including EO-1, the Wilkinson Microwave Anisotropy Probe, the Tropical Rainfall Measuring Mission, ICESat, and many others. Few other organizations offer the same level of design, build, and deployment capabilities. Engineers now are developing avionics for the Solar Dynamics Observatory, Lunar Reconnaissance Orbiter, and the James Webb Space Telescope Integrated Science Instrument Module. The tried-and-true techniques that GSFC has applied to these missions also pertain to human spaceflight.



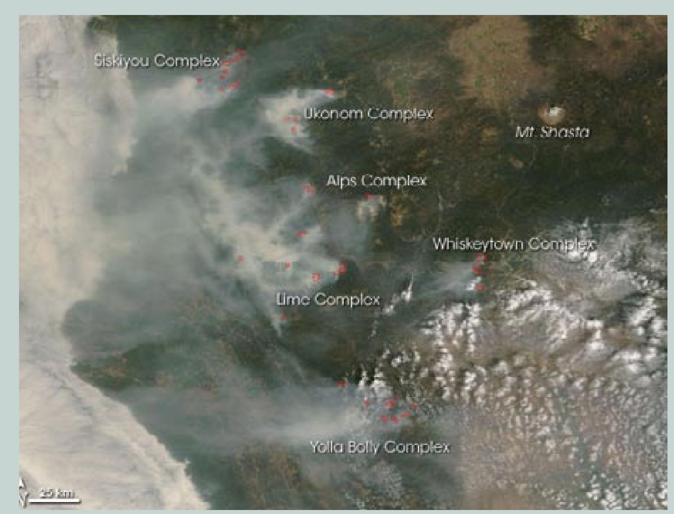
GSFC'S ultra-low power, radiation-hardened microelectronics technology dissipates a fraction of the power of conventional spaceflight-capable electronics.

Avionics Approach Avionics systems engineers use long-established principles from the robotics community, which also requires radiation-tolerant technologies, end-to-end testing, power minimization, fast and autonomous fault detection and correction, and safe-mode operations. These principles also are critical to human spaceflight; and GSFC's approach is scalable, from small robotic missions to larger exploration-related missions. Avionics designs maximize reliability, while addressing mass, power, volume, cost, and schedule constraints. In addition, GSFC uses integrated safety and design analyses to determine the level of failure tolerance. For critical-1 designs, this results in the safest practical system to accomplish a mission. Contact: James.R.Morrissey@nasa.gov.

Low-Power Microelectronics Architectural options for lunar surface systems are significantly increased if power constraints can be relaxed. GSFC's ultra-low power, radiation-hardened microelectronics technology facilitates this goal by dissipating a fraction of the power of conventional spaceflight-capable electronics. It was flight-validated onboard the ST-5 mission. Contact: Pen-Shu.Yeh-1@nasa.gov.

For ground and surface systems, the Goddard Mission Services Evolution Center allows for the plug-and-play of more than 50 COTS and GOTS mission-operations center products.

Radiation Effects and Analysis Group (REAG)
This highly specialized organization has decades of experience analyzing and assuring that spaceflight systems can withstand the effects of radiation. It achieves this through an end-to-end systems engineering approach that emphasizes risk assessment and system-level mitigation. Products include mission-specific analyses, 3-D ray traces, the development of radiation-environment specification requirements, and recommendations for risk levels and mitigation techniques. GSFC characterizes the radiation response of commercial and emerging technologies through testing and simulation. Testing is performed at Co-60, high-energy proton, and heavy-ion facilities. GSFC test facilities include Van de Graaff accelerators, a Co-60 chamber, and alpha-source test fixtures. Contact: Ken.LaBel@nasa.gov.



Delivering real-time satellite imagery to firefighters and public health officials is made possible by GSFC's sensor-web technology, which integrates space and land assets and allows users to task sensors using the Internet.

Software

The Center builds and operates a wide variety of space mission-related software systems, including those used in both mission operations and flight dynamics facilities and for science data processing, analysis, archiving, and distribution. Critical in the design of these systems are the architecture approaches that allow for interoperability, technology infusion, and maintainability of mission-critical, long-duration systems. Advanced software capabilities have been developed at GSFC to address these key challenges and allow for new levels of situational awareness and system automation.

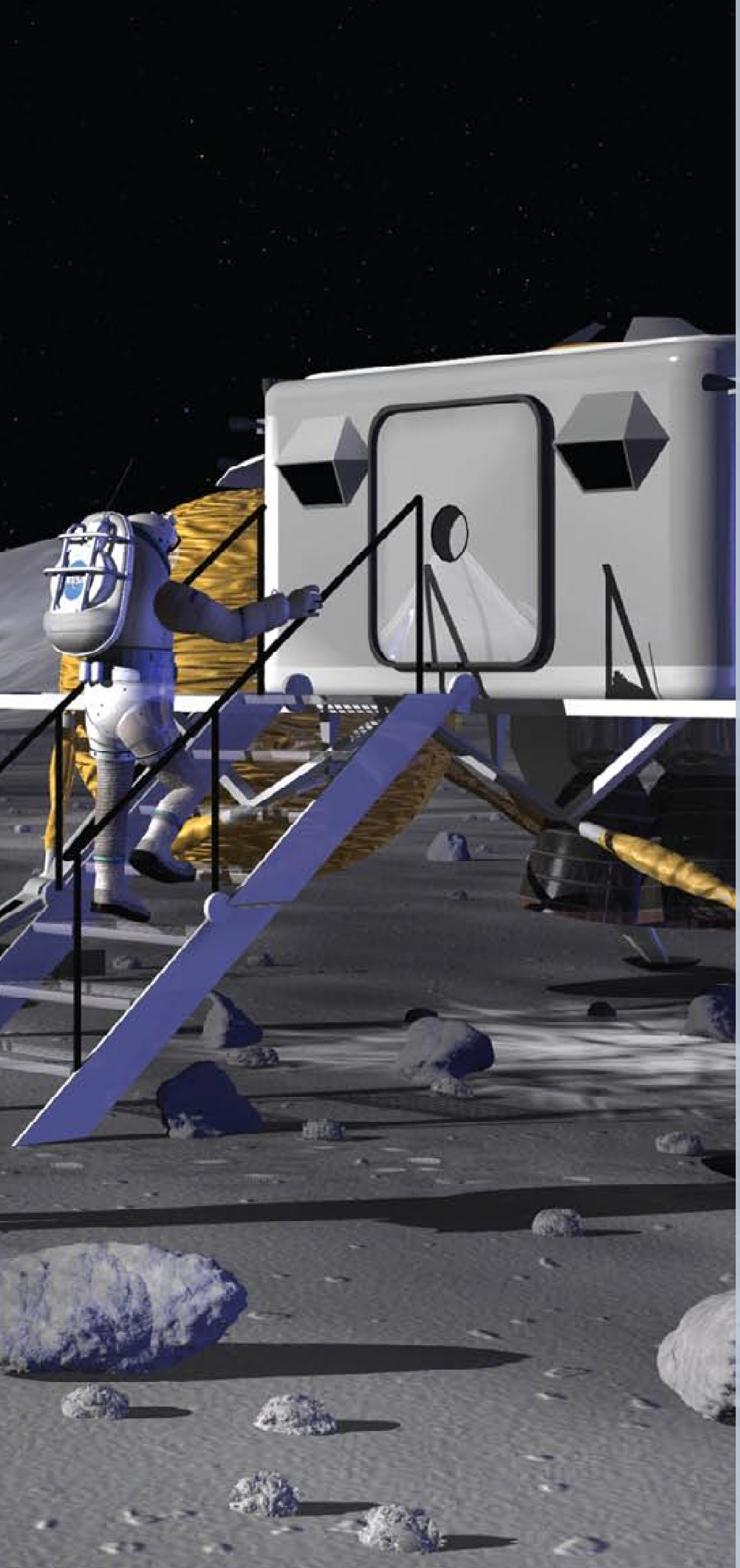
Core Flight System (CFS) CFS provides common services and a plug-and-play capability for flight instruments and command-and-data handling software systems. Well-defined interfaces, common components, and configurable system settings greatly simplify a flight system's mission-critical software development and testing. Contact: Jonathan.J.Wilmot@nasa.gov.

Goddard Mission Services Evolution Center (GMSEC) GMSEC is a set of software components, interface standards, and an open architecture, which, together, simplify the integration and development of ground- and flight-data systems. Because it standardizes interfaces — not components — and provides a middleware infrastructure, GMSEC also eases the infusion of new technologies, supports evolving operational concepts, and allows the growth of current and future missions. These benefits enable new levels of situational awareness and automation and ultimately reduce the cost and complexity of operating long-term and complex mission software systems. Contact: Danford.S.Smith@nasa.gov.

Sensor Web 2.0 This tool enhances plug-and-play capabilities by transforming existing protocols into Web services, workflows, news feeds, browsers, and search engines. The architecture makes use of standards developed by the Open Geospatial Consortium (OGC) and the Workflow Management Coalition (WfMC). More than 350 organizations belong to OGC and WfMC, including Google, Yahoo, NOAA, NASA, and the United Nations, to name a few. The architecture integrates multiple underlying standards, including C3I, CCSDS, and IP. Contact: Daniel.J.Mandl@nasa.gov.

Lunar Operations Analyzer (LOA) Human missions to the Moon will be complex and potentially dangerous. To assure mission success, designers and mission planners will have to know whether spacesuits, habitats, rovers, power and information systems, and other surface elements meet operational needs under a diverse set of configurations and scenarios. The LOA will provide that information in an easily comprehensible color-coded matrix. Contact: Mark.L.Lupisella@nasa.gov.

Human and Robotic Surface Operations and Serviceability

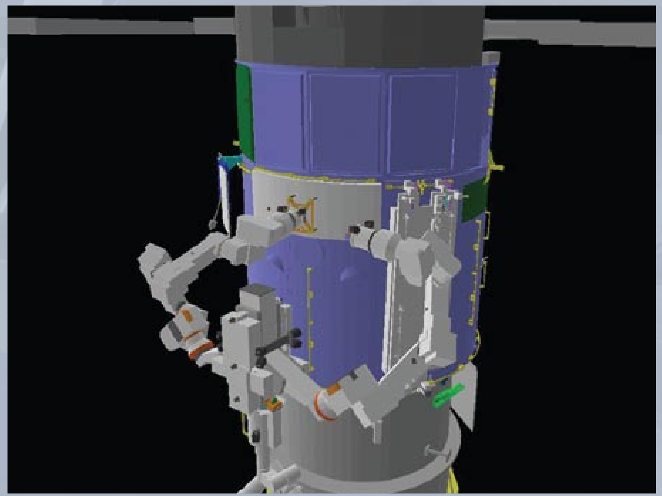


GSFC developed the processes and tools needed to carry out Hubble Space Telescope servicing missions. This unique skill-set is directly applicable to the Exploration Systems Mission Directorate, whose mission will require the human and robotic servicing of different types of lunar surface equipment.

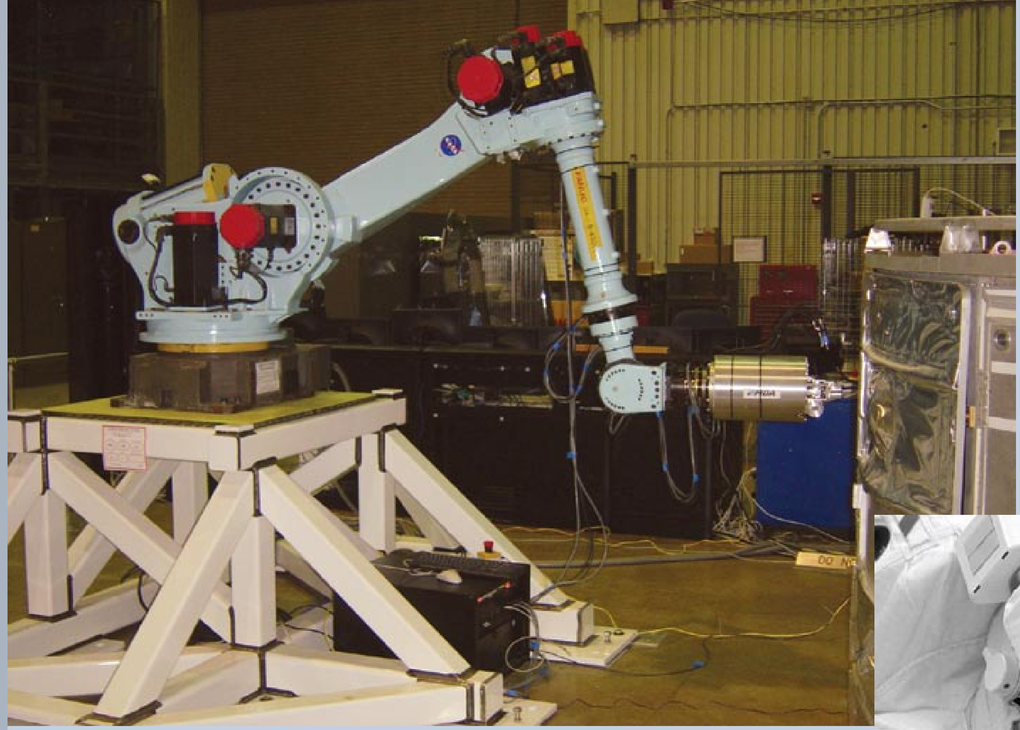
Robotic Surface Operations and Serviceability

Tapping its considerable experience designing a fully serviceable Hubble Space Telescope and executing four servicing missions over the last 15 years, GSFC performed a trade study looking at the modularity and serviceability needs of lunar surface systems. Based on the results, the Center demonstrated some of the more important servicing tasks and will be testing a few of the critical technologies under various environmental conditions. Contact: Brian.Roberts@nasa.gov.

Contact Dynamics Simulation Goddard has developed a facility that allows dynamic hardware-in-the-loop simulations of any space robot interacting with its environment. In the facility, engineers can use a computer program to simulate the kinematic and dynamics response of a space robot. The operator controls the simulated robot arm and an industrial robot, with an end effector placed on the end, imitates the motion and response of the simulated arm's end point. This allows robot-arm designers to optimize their designs before building the actual flight arm. Once the flight arm is built, the facility can be used to verify procedures and timelines. Contact: Brian.Roberts@nasa.gov.



While planning the Hubble Robotic Servicing and Deorbit Mission, a GSFC team participated in an intense exercise that included, among other things, analyzing each robotic task to determine the best body position for access to all interfaces as well as the placement and use of tools at the worksite.



GSFC has developed a facility that allows dynamic hardware-in-the-loop simulations of any space robot interacting with its environment.

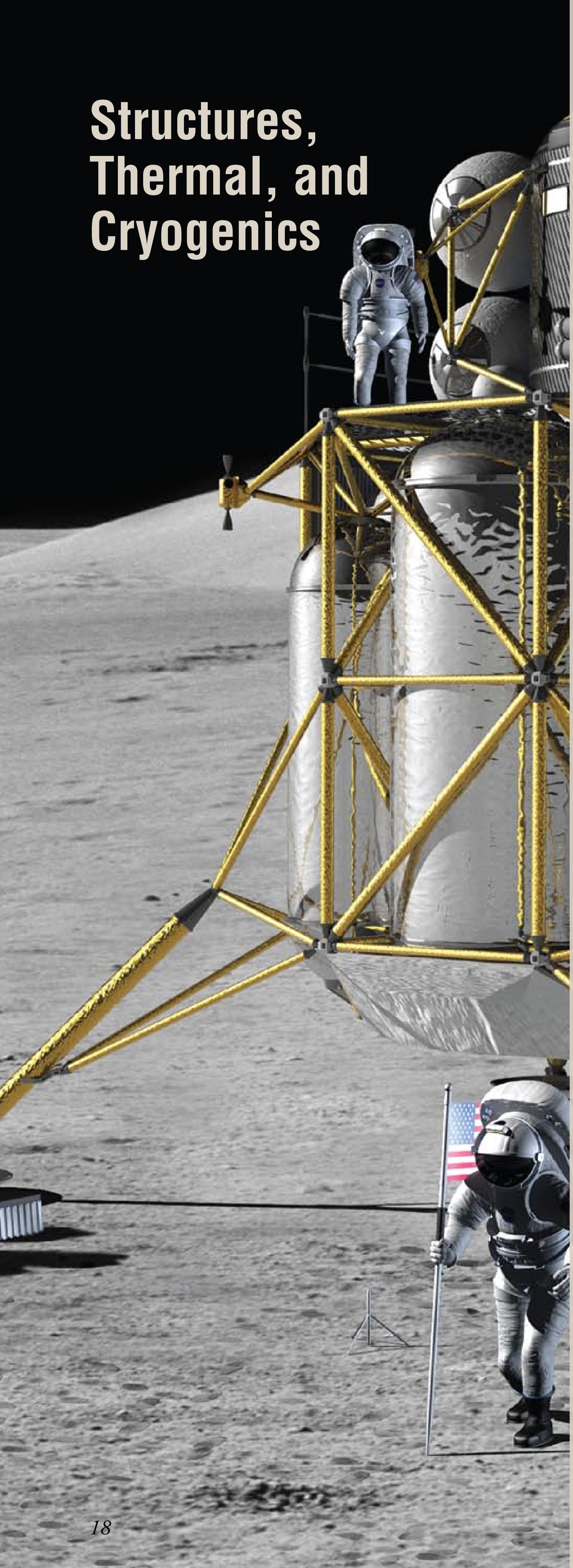
Health Monitoring and Trending Designing full redundancy into lunar surface systems to mitigate every possible failure over a 5-year mission will dramatically increase the mass, complexity, and cost of transporting these systems to the Moon. To assure reliable performance without the benefit of full redundancy, a lunar surface system must be able to self-diagnose and repair problems on the lunar surface. The Center's objective is to create a rugged, miniaturized box — the Diagnostics and Power Port — that enhances a system's command-and-data handling functions by forecasting a possible problem before it happens, diagnosing it when it does occur, devising possible repair options, and promptly reporting the forecasts or diagnoses and repair options to controllers on the ground, an astronaut, or a rover. Contact: Brian.Roberts@nasa.gov.

Dexterous Robotics While planning the Hubble Robotic Servicing and Deorbit Mission, a GSFC team participated in an intense design process that included documenting all requirements and showing flow-down and traceability; conducting a kinematic analysis of each robotic task to determine the best body position for access to all interfaces as well as the placement and use of tools at the worksite; analyzing whether a task can be completed without changes to the basic robot parameters; and carrying out hardware simulations using testbed robotic arms and neutral buoyancy facilities. Contact: Jill.McGuire@nasa.gov.

Shown here is one of many tools GSFC developed for the Hubble Space Telescope servicing missions.

Tool and End Effectors GSFC has more than 20 years of experience designing crew aids and tools to service the Hubble Space Telescope. As part of its work, the GSFC team spent a year designing tools and the stowage system for the Hubble Robotic Servicing Mission — a challenge that required the development of 24 unique and innovative tools that will work with interfaces that were not designed for robotic manipulation. The tools were designed and successfully demonstrated mating and de-mating connectors, opening and restraining doors, managing harnesses, and providing a means to manipulate high-precision optical instruments through multi-functional adapter plates. Contact: Jill.McGuire@nasa.gov.

Structures, Thermal, and Cryogenics



Responsibility for managing and developing missions that have pushed the boundaries in scientific discovery has required GSFC technologists to acquire expertise in a variety disciplines, including structures, thermal, and cryogenics. The same technologies and expertise can be leveraged to meet exploration challenges.

Composite Structures

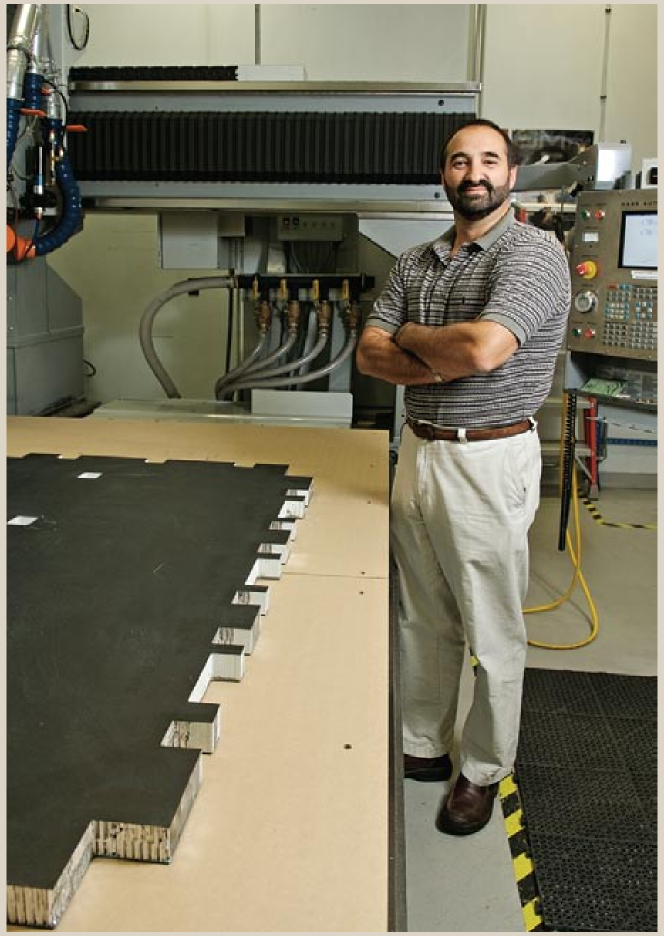
More than 20 years ago, Center engineers recognized the promise of composite materials in science-instrument design and developed an end-to-end engineering specialty in the field. Today, the Mechanical Systems Division is one of the few government organizations to offer the gamut in composite materials engineering, from design, analyses, fabrication, and assembly to structural verification. The division has built composite structures for such high-profile missions as the Hubble Space Telescope, Gamma-Ray Large Area Space Telescope, Solar Dynamics Observatory, Swift, and ICESat. The division is now broadening its expertise to offer solutions geared specifically to human spaceflight and the Constellation program. Contact: Kenneth.N.Segal@nasa.gov.

Enhanced/Multi-Functional Nano Structures

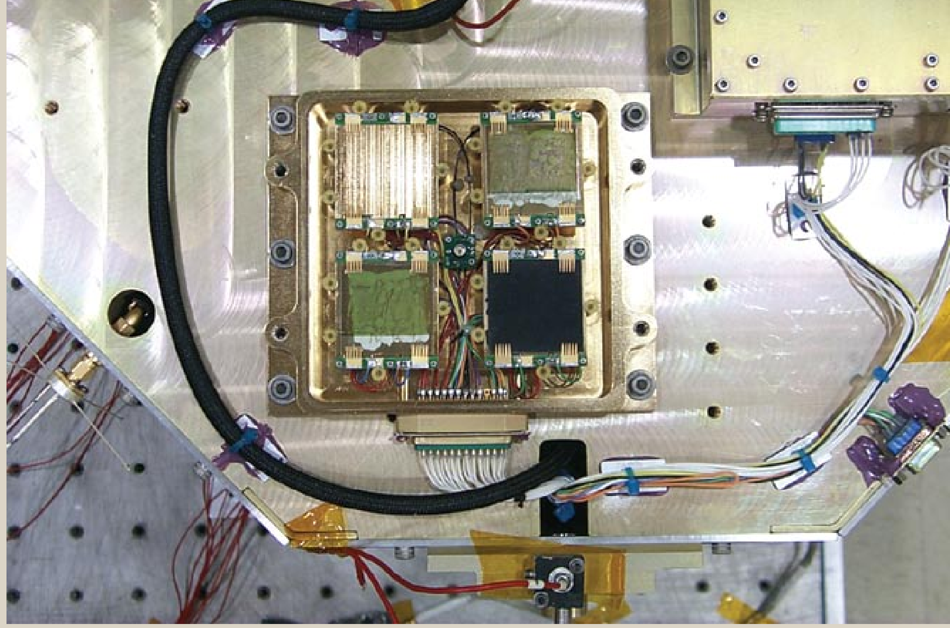
Constructing the Altair Lander with carbon-fiber reinforced polymer (CFRP) composite materials will reduce the spacecraft's mass and potential for component failure and generally simplify its design. A GSFC-led nano-CFRP development team can make mission-specific nano-CFRP property-enhancement capabilities available to the Altair and lunar habitat teams. The team also will demonstrate "net-shape" configuration control for individual nano-CFRP components by delivering a representative sample of primary-structure strut engineering test units developed for the Magnetospheric Multiscale Mission. Ultimately, the nano-CFRP production techniques, tools, composite formulations, and microstructure-to-property models will allow GSFC to directly support lunar surface system missions, enabling unprecedented mission capability and performance. Contact: Dan.Powell@NASA.gov.

Thermal Analysis of the Lunar Environment

The lunar thermal environment poses a significant engineering challenge. During the day, effective thermal sink temperatures may approach 130°C, while at night, they may sink to –200°C or below. This variation from hot to cold makes it difficult to maintain normal room temperatures for the astronauts and their equipment. For example, heat pumps or special radiators may be needed during the peak of the day. As the lead organization for the Lunar Reconnaissance Orbiter, which will orbit the lunar surface at about 50 km and will therefore experience a very similar environment as on the surface, GSFC has made a major effort to understand and accurately model this widely varying thermal environment. This has included both model development as well as evaluation of all available environmental data from Apollo, Clementine, and astrological observations. Contact: Theodore.D.Swanson@nasa.gov.



More than 20 years ago, GSFC recognized the promise of composite materials in spacecraft design and developed an end-to-end engineering capability in the field. Shown here is a sample composite structure.



This image shows the Eclipse Electrochromic Test Module that GSFC was instrumental in having mounted to the top of MidSTAR-1. Recent flight data indicate that this first-generation variable-emittance coating is operating more than a year after the satellite's launch.

Variable Emittance Coatings (VECs)

Electrochromics, a type of thin-film VEC that can be applied to equipment surfaces, offers a practical solution for modulating the rate of heat rejection or absorption on radiators. GSFC is leading the effort to develop VEC technologies and is currently working with private companies to develop a second-generation electrochromics film. In 2006, the team demonstrated two first-generation VEC concepts on the ST-5 mission. Contact: Theodore.D.Swanson@nasa.gov.

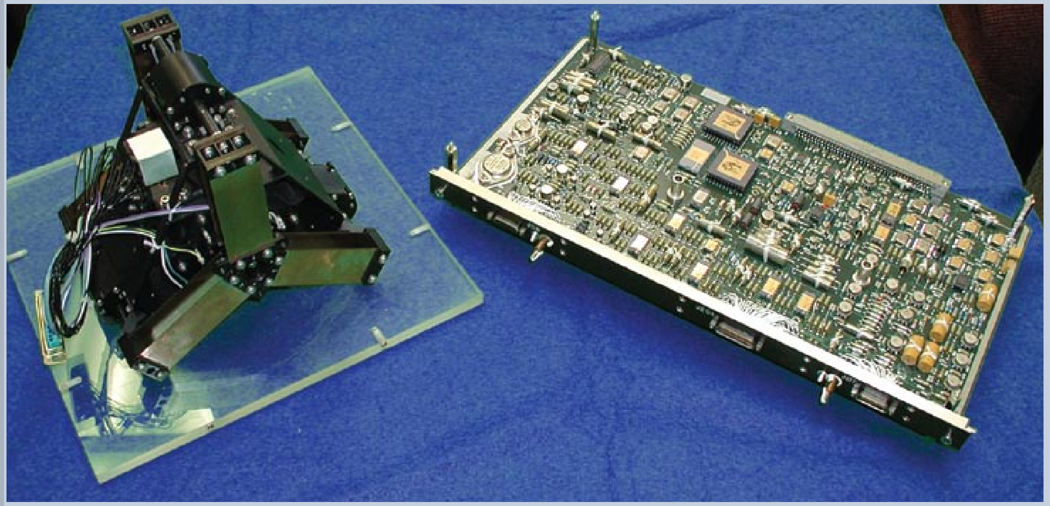
Cryo-Storage/Zero Boiloff

Cryogenic storage offers a compact, lower-pressure mode for storing oxygen, hydrogen and perhaps methane. This can translate to lowered system mass. GSFC's experience in building and integrating both liquid cryogen systems and cryocoolers for science payloads is being leveraged to satisfy the needs of lunar surface systems operations. Areas under study include integration of coolers with cryogenic storage tanks, dual-cryogen or co-storage systems, high-pressure, low-temperature storage for hydrogen, and system tradeoffs for low-temperature storage of fuel-cell reactants. Contacts: Robert.F.Boyle@nasa.gov or Edgar.R.Canavan@nasa.gov.

Mechanisms, Interfaces, and Payloads

GSFC has decades of experience fabricating, integrating, testing, and operating major structural and deployable mechanical and electromechanical subsystems and interfaces. Examples of the Center's ability to achieve precise, repeatable results — a GSFC hallmark — can be found in its groundbreaking work on the Solar Maximum, Space Shuttle Hitchhiker, and Hubble Space Telescope servicing missions. GSFC is now leveraging this expertise to develop instrument-carrier systems for the Orion Service Module and the ARES V. It also is studying a system that can transport and support experiments on the Moon's surface.

This image shows a top down view of the Orbital Replacement Unit Carrier used during the third Hubble servicing mission.

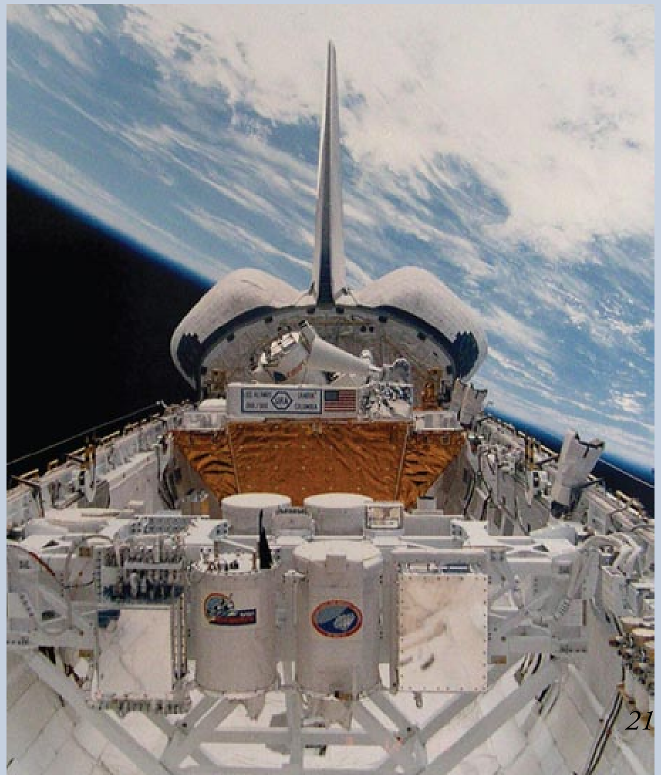


For the Cassini Infrared Spectrometer, which measured infrared emissions from Saturn's atmosphere, rings, and surface, GSFC engineers developed the instrument's scan mechanism (left) as well as the electronics to drive the device (right).

Spaceflight Mechanisms GSFC is a recognized world leader in cryogenic space mechanisms, as evidenced by its work on the Wilkinson Microwave Anisotopy Probe, the Nobel-prize winning Cosmic Background Explorer, the Spitzer Space Telescope, and the Cassini-Huygens mission. In addition, GSFC has a 35-year history of developing highly reliable, man-rated mechanisms. Examples include those developed for the Hubble Space Telescope, Upper Atmosphere Research Satellite, Compton Gamma Ray Observatory, and the Solar Maximum Mission. This rich combination of experience gives GSFC the unique ability to provide crew and robotic mechanisms that can operate under the Moon's harsh environmental conditions. Contact: Jason.G.Budinoff@nasa.gov.

Extravehicular Activity Tools The Center has more than 20 years of experience designing crew aids and tools for servicing satellites in space. Most recently, the team managed and developed most of the 150 unique tools needed for the upcoming Hubble Space Telescope servicing mission. For a previous servicing mission, GSFC developed the Pistol Grip Tool, which is now used on International Space Station construction and servicing missions. GSFC engineers also collaborated closely with the Johnson Space Center and the Langley Research Center to design, test, and build new tools for the Shuttle's return to flight. Contact: Jill.McGuire@nasa.gov.

Shuttle Small Payloads Project (SSPP) and the Hitchhiker Program GSFC created the SSPP in the mid-1980s to develop low-cost science and technology payloads for the Space Shuttle. GSFC's in-house Hitchhiker program designed the carrier system and supported crew training and mission operations. Hitchhiker missions were developed at relatively low costs and within short turn-around periods, especially compared with other Shuttle payloads. As a result, the program provided mission opportunities to hundreds of experimenters, from preschool students to the international science community, and made possible a wealth of scientific data, discoveries, and technology demonstrations. Work is now underway to develop accommodations for the Orion Service Module and ARES V as well as a carrier system that will transport and support experiments on the Moon's surface. Contact: Michael.R.Wright@nasa.gov.



The GSFC-developed Shuttle Hitchhiker provided hundreds of mission opportunities for the international science community, making possible a wealth of scientific data.

Mobility and In Situ Resource Utilization

The Moon is an inhospitable place, distinguished by deep impact craters, rocky highlands, and extreme environmental conditions. To explore Earth's only natural satellite, NASA will need to establish a variety of bases, scientific outposts, and other facilities that may be placed kilometers from astronaut habitats. Living and working under such difficult conditions will require new forms of mobility and the capability to create energy and even oxygen from the Moon's natural resources.

In-Situ Flyer The In-Situ Flyer will give astronauts the ability to conduct science investigations in diverse and distant geographical areas—a capability not possible with more traditional rover systems. Based on the Lunar Explorer (LEx) mission concept, the flyer is a measurement-mobility system derived from Defense Department-tested propulsion technologies. The flyer will be able to "fly to" any area within 150 km of a human-sortie landing site and give unprecedented access to rugged terrains not navigable with rovers. Contact: James.B.Garvin@nasa.gov.

Vacuum pyrolysis uses heat to incinerate lunar soil and rock to extract oxygen bound up in the Moon's regolith. GSFC engineers have shown that the required temperature to release the oxygen is much lower than previously thought.

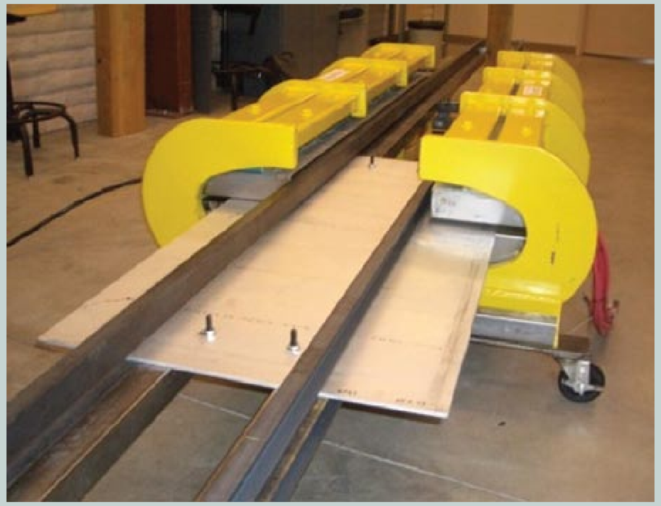
Traditional four-wheeled robots one day could be replaced by a new generation of rovers that change shape to navigate difficult terrain. Shown here is an early prototype of the Tetrahedral Walker concept.

Tetrahedral (TET) Walker

Traditional four-wheeled robots, similar to those now roving the surface of Mars, could one day be replaced by a new generation of rovers that change shape to navigate difficult terrain. GSFC engineers and scientists are now working on the third-generation Tetrahedral Walker equipped with nodes and struts that expand and retract to change its center of gravity, causing it to topple over and move. Contact: Steven.A.Curtis@nasa.gov.

Vacuum Pyrolysis Vacuum pyrolysis is an efficient technique for extracting oxygen bound up in lunar soil and rock. Instead of using chemicals to reduce the oxygen, vacuum pyrolysis incinerates the rock and soil in a vacuum. The soil vaporizes and releases gaseous oxygen that then can be pumped and stored in holding tanks for eventual use as breathable oxygen or propellant. A GSFC team has demonstrated and continues to work on a vacuum-pyrolysis chamber that uses resistive heating, showing that the approach can extract small amounts of oxygen. Contact: Eric.H.Cardiff@nasa.gov.

Electromagnetic Launch Assist (EMLA) In 2004, GSFC directed a collaborative effort involving 50 engineers and scientists from six NASA Centers, the Defense Department, industry, and academia to investigate different aspects of an EMLA system. It ultimately partnered with Dryden Flight Research Center under an Innovative Partnership Program effort to develop an EMLA testbed. Recent testing showed speeds of 156 mph, with a 300-mph test planned for fall 2008. The potential applications of such a system include ground-based launch assists to increase mass-to-orbit as well as a non-propellant system for launching small masses from the lunar surface to orbiting depots. Contact: Michael.R.Wright@nasa.gov.



GSFC has partnered with Dryden Flight Research Center under an Innovative Partnership Program effort to develop an electromagnetic launch assist testbed. Recent testing showed speeds of 156 mph, with a 300-mph test planned for fall 2008.

Pre-Flight Integration and Risk Reduction

GSFC's 251,400-square-foot I&T complex offers the largest laminar-flow facility, state-of-the-art optical alignment, and qualification under launch and space environments.

GSFC has a long history of developing, integrating, and testing spaceflight systems. Its strength comes from its highly qualified technical and management workforce and state-of-the-art facilities. GSFC projects have included everything from Apollo-era lunar instruments and Shuttle small payloads, to Spartan and the Hubble Space Telescope.

Systems Engineering GSFC's technical breadth and depth in planning, designing, and implementing next-generation robotic and manned scientific missions make the Center's systems engineering organization unique at NASA. System engineers provide technical leadership for all flight- and ground-system elements, including the collection and distribution of instrument data. Their expertise includes the development and operation of rocket and balloon payloads, expendable launch vehicle systems, small- and medium-sized unmanned robotic explorers, large Earth and space astronomical observatories, and communications satellites. In short, this "cradle-to-grave" systems experience carries across all areas important to NASA, including exploration, advanced communications, Earth science, space science, launch systems, and manned spaceflight arenas. Contact: Kenneth.E.Yienger@nasa.gov.

Integration and Test (I&T) For nearly 50 years, GSFC has provided both the expertise and facilities for integrating and testing spaceflight hardware. Experience includes the development, fabrication, and testing of everything from extravehicular activity tools and Shuttle carriers, to satellite ejection systems and deep-space instruments. In addition, the 261,400-square-foot I&T complex offers cleanrooms that include the largest laminar-flow facility, state-of-the-art optical alignment, and qualification under launch and space environments. All services are provided within the same complex, reducing risk by eliminating the necessity to move flight hardware from one building to another. Contact: Carmine.F.Mattiello@nasa.gov or Michael.R.Wright@nasa.gov.

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